Dynamical behavior of coupled chaotic oscillators including phase synchronization and complete synchronization in plasma

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The dynamical behavior of two coupled chaotic oscillators caused by the current-driven ion acoustic instability is experimentally studied. It is found that when two oscillators (two unstable waves) are interacting, and the dc potential applied to either of the two oscillators is varied gradually while maintaining coupling, the two oscillators synchronize in a certain region.

1. Introduction

Recently, the synchronization of two chaotic oscillators[1] has attracted much attention in many branches of science, motivated by the possibility of wide spread applications of coupled nonlinear oscillators. It is well known that two chaotic oscillators can synchronize through interaction, namely, coupling. This synchronization has useful applications in chaos control.[2] Coupled nonlinear oscillators exhibit a variety of fundamental dynamical phenomena in addition to the synchronization of mutual chaotic oscillators. The dynamical behavior of the coupled nonlinear oscillators including chaos synchronization has been studied in laser systems,[3] the electronic circuits[4] and so forth. The behaviors of coupled nonlinear oscillators are interesting phenomena in the study of plasma physics as well as other branches of science.

We have study the dynamical behavior of two coupled chaotic oscillators caused by the current-driven ion acoustic instability.

2. Experimental set up

The experiments are performed using a Double Plasma device. Argon gas is introduced into the chamber at a pressure of 4.0×10^{-4} Torr. Typical plasma parameters are as follows: the electron density $n_e \sim 10^8$ cm^{-3}, electron temperature $T_e \sim 0.5$-1.0 eV.

The current-driven ion acoustic instability is excited by the two parallel mesh grids installed into the chamber (G_1 and G_2). The dc potential V_m is applied to the mesh grid G_1 and V_S is applied to the mesh grid G_2 in order to excite the current-driven ion acoustic instability. V_m and V_s are control parameters which govern instability-1 and instability-2, respectively. Thus, interaction of two unstable waves (instabilities), namely coupling, is made.

Time series signals for analysis are obtained from the fluctuating components of the currents on the biased mesh grids on both ends (G_1 and G_2), and are sampled with a digital oscilloscope.

Figure 1 and 2 show schematic diagram of the experimental apparatus and chart of experimental setting, respectively.

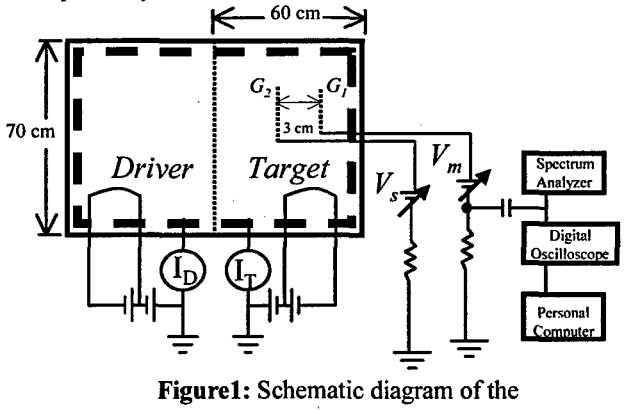

Figure1: Schematic diagram of the experimental apparatus.

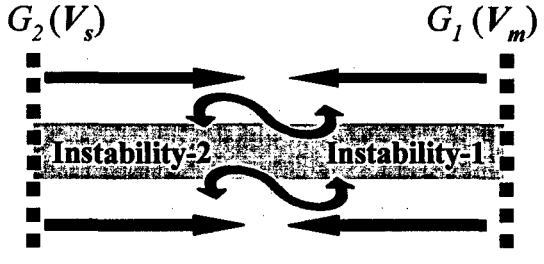

Figure2: Schematic of coupling of two oscillators.

3. Experimental results and discussions

When the grid bias exceeds a threshold, the current-driven ion acoustic instability is excited. We investigate the behavior of the coupled system where two chaotic oscillators caused by the instability interact. We change V_m gradually and the control parameter V_s governing instability-2 is fixed at 53 V.

For 0 V < V_m < 24 V, only instability-2 oscillates since instability-1 is not yet excited in this range of the parameter. For 24 V < V_m < 38 V, instability-1 is also excited and the system does not reach the synchronization state, as shown in Fig. 3. Figure 3(a) and (b) shows the time series of the signals and the X - Y plot of the two instabilities shown in (a). For 38 V < V_m < 60 V, the phase synchronization[5] is observed. With increasing V_m, the two oscillators synchronize gradually, and finally for 60 V < V_m < 64 V, the complete synchronization is observed, as shown in Fig. 4. For V_m > 64 V, instability-1 vanishes gradually.

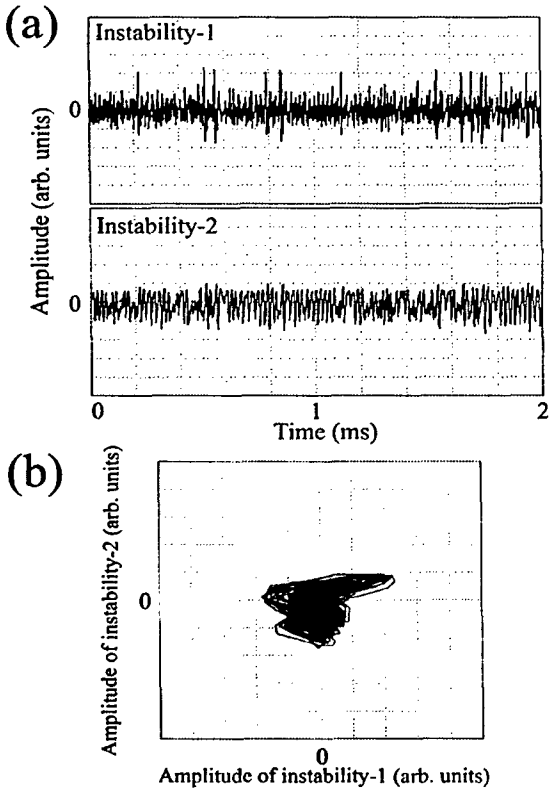

Figure3: Non synchronized state.

(V_m = 33V, V_s = 53V)

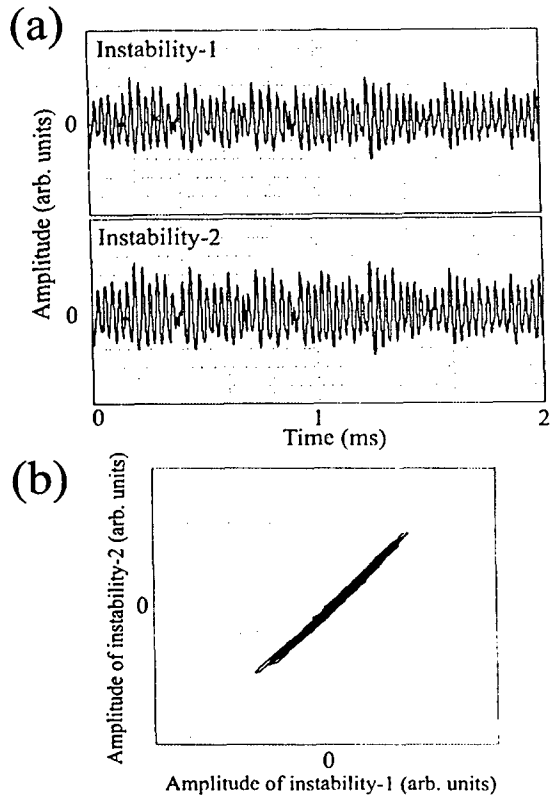

Figure4: Complete synchronized state.

(V_m = 62V, V_s = 53V)

4. Conclusion

Two oscillators caused by the current-driven ion acoustic instability have been coupled through the interaction of two unstable waves. When the control parameter V_m of instability-1 is changed gradually, with V_s fixed at 53 V, phenomena such as "phase synchronization" and "complete synchronization" have been observed. Thus, dynamical behavior of two coupled chaotic oscillators by mutual coupling has been observed in plasma.[6]

5. References

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